REMARKS/ARGUMENTS

Reconsideration of this application in light of the above amendments and following comments is courteously solicited.

The invention as claimed in amended claim 1 is directed to a metal/ceramic bonding substrate comprising: a ceramic substrate; a metal circuit plate bonded to one side of said ceramic substrate; a heat sink plate of a metal, one side of which is bonded to the other side of said ceramic substrate; and a work-hardened layer of the same material as said metal, formed on the other side of said heat sink plate, said work-hardened layer being formed by colliding ceramic or glass balls with the other side of said heat sink plate. Thus, according to the invention as claimed in amended claim 1, it is possible to provide a metal/ceramic bonding substrate capable of preventing the reverse thereof from greatly warping so as to be concave even if it is heated for soldering.

In general power modules, a ceramic insulating substrate is fixed by soldering to one side of a metal plate or compound material called base plate, and power ICs are fixed by soldering to the ceramic insulating substrate. On the other side (reverse) of the base plate, a radiating fin or cooling jacket of a metal is mounted via a thermal conduction grease by means of screws.

Since the soldering of the base plate and power ICs on the ceramic insulating substrate is carried out by heating, the base plate is easy to warp due to the differential coefficient of thermal expansion between bonding members during soldering. Heat generated by the power ICs passes through the ceramic insulating substrate, solder and base plate to be radiated from the radiating fin or cooling jacket to air or cooling water. Therefore, if the base plate warps during soldering, clearance increases when the radiating fin or cooling jacket is mounted on

the base plate, so that there is a problem in that the heat sink characteristic of the substrate extremely deteriorates.

That is, each of the base plate, radiating fin and cooling jacket is made of a metal, and warps to some extent. Therefore, even if the base plate is caused to contact the radiating fin or cooling jacket, there are non-contact portions therebetween, so that it is not possible to obtain efficient heat conduction. In order to compensate for this, a thermal conduction grease is applied on the base plate and/or the radiating fin or cooling jacket to cause the radiating fin or cooling jacket to tightly contact the base plate. However, the thermal conductivity of the thermal conduction grease is a few W/m which is far smaller than that of other members, such as the base plate. Thus, in order to prevent heat sink characteristic from deteriorating due to the thermal conduction grease, the thermal conduction grease having the minimum thickness of tens to hundreds micrometers necessary to compensate for the fine warpage of the base plate or the like is usually provided between the base plate and the radiating fin or cooling jacket. However, if only the base plate warps by one hundred micrometers, the thickness of that portion of the thermal conduction grease increases by one hundred micrometers, so that heat sink characteristic deteriorates.

In particular, if the reverse of the base plate greatly warps so as to be concave, it is a deathblow, and the thickness of the thermal conduction grease on the central portion of the base plate increases. In order to avoid this, the base plate is usually caused to previously warp by a mechanical operation, and a side of the base plate on which the radiating fin or cooling jacket is to be mounted is caused to warp so as to be flat or convex.

In the case of a metal/ceramic circuit board wherein a base

plate of aluminum or an aluminum alloy is bonded directly to a ceramic insulating substrate without the need of soldering, it is not required to solder the base plate on the ceramic insulating substrate, so that thermal conductivity is improved therebetween. However, it is required to solder power ICs on the circuit, so that it is required to cause the reverse of the base plate to warp so as to be as flat or convex as possible after heating.

In order to produce the metal/ceramic circuit board wherein the base plate of aluminum or an aluminum alloy is bonded directly to the ceramic insulating substrate without the need of soldering, molten aluminum is poured onto the ceramic substrate in a shape corresponding to that of the base plate, and solidified to bond an aluminum plate to the ceramic substrate. When such a metal/ceramic circuit board is caused to pass through a furnace in order to solder power ICs, if the base plate and the ceramic substrate contacting therewith are large, the reverse of the base plate tends to be easy to greatly warp so as to be concave. Thus, if the reverse of the base plate greatly warps so as to be concave, there is a problem in that the heat sink characteristic of the metal/ceramic circuit board deteriorates due to bad adhesion between the heat sink plate and the radiating fin or cooling jacket.

In order to solve such a problem, the inventors have diligently studied and found that it is possible to prevent the reverse of a metal/ceramic bonding substrate from greatly warping so as to be concave if the reverse of the heat sink plate is hardened to form a work-hardened layer thereon by the shot peening for colliding ceramic or glass balls with the reverse of the heat sink plate.

If balls, such as ceramic or glass balls, are caused to collide with a heat sink plate of a metal, such as aluminum or

copper, a surface portion having a thickness of a few to hundreds micrometers is hardened by the peening effect to form a work-hardened metal layer.

If the work-hardened layer hardened by the peening effect is arranged on the reverse of the heat sink plate, the extending amount of the reverse due to thermal expansion during heating for soldering is greater than the contracting amount of the reverse due to thermal contraction during cooling, so that the reverse of the heat sink plate can warp so as to be convex after heating.

Since a relatively high pressure is required to obtain the peening effect, ceramic balls having a spherical shape and being difficult to be deformed are preferably used as balls capable of being repeatedly used under a high pressure. If the heat sink plate is a soft plate, such as an aluminum or copper plate, there is a problem in that balls to be caused to collide therewith stick into the heat sink plate. Therefore, ceramic balls capable of maintaining the spherical shape and having a high strength are preferably used. The ceramic is preferably zirconia being difficult to wear off and having a high strength, although it may be alumina.

When the metal circuit plate and the heat sink plate are bonded directly to the ceramic substrate, it is difficult to previously cause the heat sink plate to warp to bond them directly to the ceramic substrate. Therefore, the metal/ceramic bonding substrate is particularly effectively applied to a metal/ceramic bonding substrate wherein the metal circuit plate and the heat sink plate are bonded directly to the ceramic substrate as claimed in amended claim 6.

Claims 1-7 were rejected under 35 U.S.C. §103(a) as being unpatentable over Nagase et al. (USP6,033,787) in view of Elmoursi et al. (US2003/0219576A1).

Nagase et al. disclose a metal/ceramic bonding substrate comprising: a ceramic substrate; a metal circuit plate bonded to one side of the ceramic substrate; a heat sink member bonded to the other side of the ceramic substrate. However, Nagase et al. fail to disclose or suggest that a work-hardened layer of the same material as a metal which is the material of the heat sink member is formed on the heat sink member. Nagase et al. also fail to disclose or suggest that the work-hardened layer is formed by colliding ceramic or glass balls with the heat sink member. Therefore, Nagase et al. fail to disclose or suggest any metal/ceramic bonding substrate having a work-hardened layer for preventing the reverse thereof from greatly warping so as to be concave even if it is heated for soldering.

Elmoursi et al. disclose a copper-based circuit wherein a layer of copper particles 101 is formed on a silver bond layer 62 formed upon a substrate 60 of alumina, aluminum nitride or the like. The silver bond layer 62 is formed for facilitating the deposition of the copper particles 101 upon the substrate 60 (see paragraph 0028). However, Elmoursi et al. fail to disclose or suggest that the work-hardened layer is formed by colliding ceramic or glass balls with the heat sink member. Therefore, the copper particles 101 are deposited on the silver bond layer 62 to form the layer of copper particles 101, although the ceramic or glass balls are not deposited on the heat sink plate of the metal/ceramic bonding substrate claimed in amended claim 1. In addition, Elmoursi et al. fail to disclose or suggest any metal/ceramic bonding substrate capable of preventing the reverse thereof from greatly warping so as to be concave even if it is heated for soldering.

Accordingly, it is believed that the amended and newly added claims patentably distinguish the invention from the prior art.

An earnest and thorough attempt has been made by the undersigned to resolve the outstanding issues in this case and place same in condition for allowance. If the Examiner has any questions or feels that a telephone or personal interview would be helpful in resolving any outstanding issues which remain in this application after consideration of this amendment, the Examiner is courteously invited to telephone the undersigned and the same would be gratefully appreciated.

It is submitted that the claims as amended herein patentably define over the art relied on by the Examiner and early allowance of same is courteously solicited.

If any fees are required in connection with this case, it is respectfully requested that they be charged to Deposit Account No. 02-0184.

Respectfully submitted,

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I, Rachel Piscitelli, hereby certify that this correspondence is being deposited with the United States Postal Service with sufficient postage as first class mail in an envelope addressed to: "Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313" on December 18, 2006.